DBP: PROCESS DESCRIPTIONS AND COST DATA

Refer to pages 1 of 12 through 8 of 12 for contaminant data, removal and reduction techniques, and process descriptions.

3A. Enhanced Coagulation and Media Filtration:

Process - Enhanced coagulation and media filtration uses the conventional chemical and physical treatment processes of chemical addition, rapid mix, coagulation, flocculation, sedimentation, and multi media filtration. A variation on this process is a patented process that involves the addition of suspended fine sand to enhance settling and a centrifugal sand recovery step. Direct filtration, which excludes the sedimentation step, is another alternative, but is not as effective for TOC removal. Chemical coagulation and flocculation consists of decreasing pH (to levels as low as 4 or 5) and increasing the feed rate of a chemical coagulant combined with mechanical flocculation to allow fine suspended and some dissolved solids to clump together (floc). There are a variety of coagulants available (e.g. aluminum sulfate, ferric chloride, ferric sulfate, poly aluminum chloride, etc.), and the choice of one depends on water quality, contaminant removal requirements, and cost. The majority of the floc and other suspended solids are removed by settling. The remaining suspended particles are removed by filtration using multi media filters.

Pretreatment - Jar tests to determine optimum pH for coagulation, and resulting pH adjustment, may be required. Polymer addition, prior to coagulation, may enhance floc formation and settling.

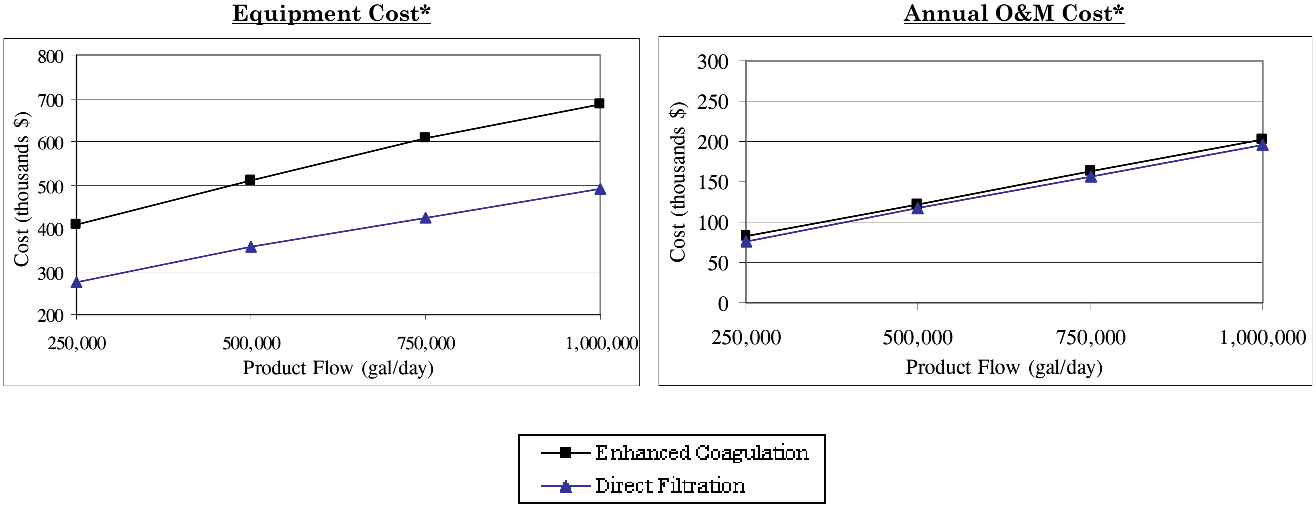
Maintenance - A routine check and possible cleaning of chemical feed equipment is necessary several times during each work period to prevent clogging and equipment wear, and to ensure adequate chemical supply. All pumps, valves, and piping must be regularly checked and cleaned to prevent buildup of carbonate scale, which can cause plugging and malfunction. Routine checks of contaminant buildup in the filter are required, as well as filter backwash. Recharging or clean installation of media is required periodically.

Waste Disposal - Filter backwash and spent material require approved disposal.

Advantages -
- Lowest capital costs for larger systems.
- Lowest overall operating costs for larger systems.
- Proven and reliable.

Disadvantages -
- Not appropriate for smaller systems.
- Operator care required with chemical handling.
- High or low pH reduces treatment efficiency.

Equipment Cost* **Annual O&M Cost***



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal. Costs presented include sedimentation.

Bureau of Reclamation, Technical Service Center
Water Treatment Engineering and Research Group, D-8230
PO Box 25007, Denver CO 80225 (303) 445-2260
Revision Date: 4/4/03

3B. Enhanced Coagulation and Microfiltration or Ultrafiltration:

Process - Enhanced coagulation and microfiltration uses the chemical and physical treatment processes of chemical addition, rapid mix, coagulation, flocculation, and sedimentation followed by microfiltration. A direct filtration approach may be used which proceeds directly from coagulation to filtration, eliminating the majority of the flocculation and all sedimentation. Chemical coagulation and flocculation consists of decreasing pH (to levels as low as 4 or 5) and increasing the feed rate of a chemical coagulant combined with mechanical flocculation to allow fine suspended and some dissolved solids to clump together (floc). There are a variety of coagulants available (e.g. aluminum sulfate, ferric chloride, ferric sulfate, poly aluminum chloride, etc.), and the choice of one depends on water quality, contaminant removal requirements, and cost. The majority of the floc and other suspended solids are removed by settling. The amount of floc and other suspended solids that can be fed to the microfilter is dependent on the membrane specifications which vary between different manufacturers and models.

Pretreatment - Jar tests to determine optimum pH for coagulation, and resulting pH adjustment, may be required. Polymer addition, prior to coagulation, may enhance floc formation and settling, but has potential problems with membrane fouling.

Maintenance - A routine check and possible cleaning of chemical feed equipment is necessary several times during each work period to prevent clogging and equipment wear, and to ensure adequate chemical supply. All pumps, valves, and piping must be regularly checked and cleaned to prevent buildup of carbonate scale, which can cause plugging and malfunction. Routine checks of membrane fouling are required, as well as filter backwash and/or chemical cleaning.

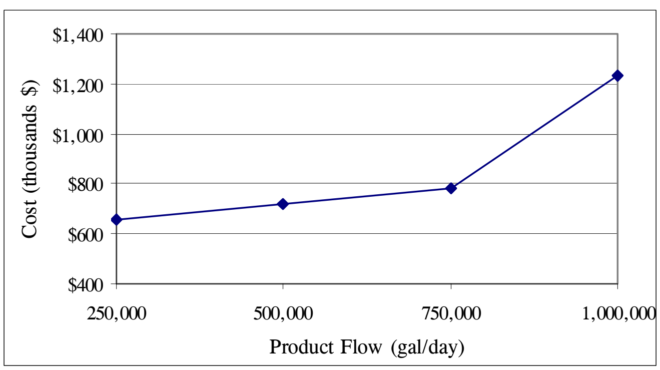
Waste Disposal - Filter backwash and spent material require approved disposal.

Advantages -
- Low capital costs for larger systems.
- Low overall operating costs.
- Proven and reliable.
- May not be appropriate for smaller systems.

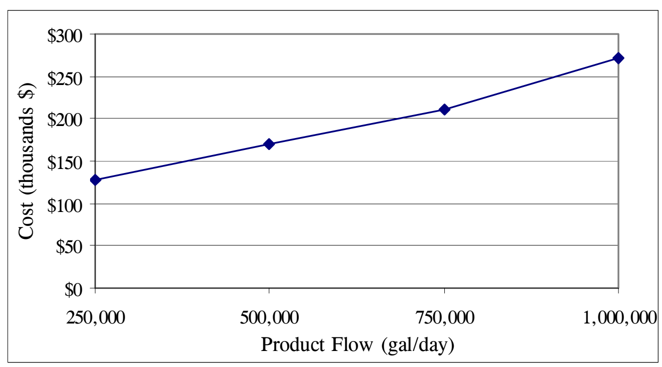
Disadvantages -
- Operator care required with chemical handling and membrane system operation.
- Higher O&M cost than media filtration.
- High or low pH reduces treatment efficiency.

Cost for Enhanced Coagulation and Microfiltration:

Equipment Cost*



Annual O&M Cost*



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal. Costs presented include sedimentation. Costs for direct filtration would be lower.

Costs for Enhanced Coagulation and Ultrafiltration:
Costs curves have not been developed at this time. Costs would be slightly higher due to higher membrane costs and increased pumping cost with higher pressures.

3C. Granular Activated Carbon:

Process - GAC uses extremely porous carbon media in a process known as adsorption. As water passes through the highly porous media which has an extremely high surface area for adsorption, the dissolved contaminants adsorb on the solid surface. GAC is made of tiny clusters of carbon atoms stacked upon one another. The carbon media is produced by heating the carbon source (generally activated charcoal) in the absence of air to produce a high carbon material. The carbon media is activated by passing oxidizing gases through the material at extremely high temperatures. The activation process produces the pores that result in such high adsorption properties. The adsorption process depends on the following factors:

1) Physical properties of the GAC, such as type of raw carbon, method of activation, pore size distribution, and surface area.
2) Chemical/electrical nature of the carbon source or method of activation, and the amount of oxygen and hydrogen associated with them, such that as the carbon surfaces become filled the more actively adsorbed contaminants will displace the less actively adsorbed ones.
3) Chemical composition and concentration of contaminants, such as size, similarity, and concentration, affect adsorption.
4) Temperature and pH of the water. Adsorption usually increases as temperature and pH decreases.
5) Flow rate and exposure time to the GAC. Low contaminant concentration and flow rate with extended contact times increase the carbon's life.

GAC devices include: pour-through for treating small volumes; faucet-mounted (with or without by-pass) for single point use; in-line (with or without by-pass) for treating large volumes at several faucets; and high-volume commercial units for treating community water supply systems. Careful selection of type of carbon to be used is based on the contaminants in the water, and manufacturer's recommendations. GAC in municipal systems can be stand alone units or associated with a multi media filter.

Biological activated carbon (BAC) is a variation of GAC and occurs when ozonated water flows through a GAC bed. This may occur to a lesser degree with non-ozonated, non-chlorinated water. BAC can more effectively remove certain contaminants than GAC.

Pretreatment - With bacterially unstable waters, filtration and disinfection prior to carbon treatment may be required. With high TSS waters, prefiltration may be required. NOM removal via coagulation, etc. can be effective in extending GAC life.

Maintenance - Careful monitoring and testing to ensure contaminant removal is required. Regular replacement of carbon media is required and is based on contaminant type, concentration, rate of water usage, and type of carbon used. The manufacturers' recommendations for media replacement should be consulted. With bacterially unstable waters, monitoring for bacterial growth is required because the adsorbed organic chemicals are a food source for some bacteria. Flushing is required if the carbon filter is not used for several days, and regular backwashing may be required to prevent bacterial growth. Perform system pressure and flow rate checks to verify backwashing capabilities. Perform routine maintenance checks of valves, pipes, and pumps.

Waste Disposal - Backwash/flush water disposal is required if incorporated. Disposal of spent media is typically the responsibility of the contractor providing the media replacement services.

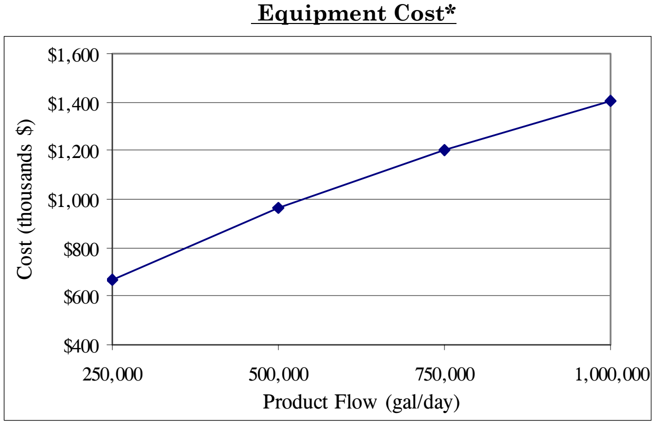
Advantages -

- Well established.
- Suitable for some organic chemicals, some pesticides, and DBPs.
- Suitable for home use, typically inexpensive, with simple filter replacement requirements.
- Reduces taste and odor problems; removes chlorine.

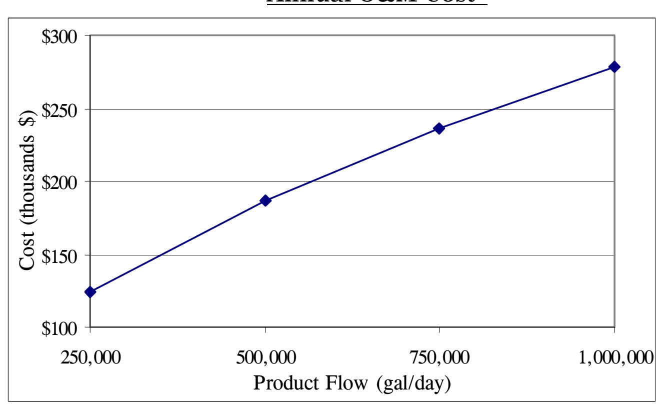
Disadvantages -

- Effectiveness is based on contaminant type, concentration, rate of water usage, and type of carbon used.
- Bacteria may grow on carbon surface (disadvantage unless BAC is preferred)
- Moderate capital expense

Equipment Cost*



Annual O&M Cost*



*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.

3D. Reverse Osmosis:

Process - RO is a physical process in which contaminants are removed by applying pressure on the feed water to direct it through a semipermeable membrane. The process is the "reverse" of natural osmosis (water diffusion from dilute to concentrated through a semipermeable membrane to equalize ion concentration) as a result of the applied pressure to the concentrated side of the membrane, which overcomes the natural osmotic pressure. RO membranes reject ions based on size and electrical charge. The raw water is typically called feed; the product water is called permeate; and the concentrated reject is called concentrate. Common RO membrane materials include asymmetric cellulose acetate or polyamide thin film composite. Spiral wound membrane construction is by far the most common; there is a very limited amount of hollow fiber RO membrane in production. Each material and construction method has specific benefits and limitations depending upon the raw water characteristics and pretreatment. A typical large RO installation includes a high pressure feed pump, parallel 1st and 2nd stage membrane elements (in pressure vessels); valving; and feed, permeate, and concentrate piping. All materials and construction methods require regular maintenance. Factors influencing membrane selection are cost, recovery, rejection, raw water characteristics, and pretreatment. Factors influencing performance are raw water characteristics, pressure, temperature, membrane type and regular monitoring and maintenance.

Pretreatment - RO requires a careful review of raw water characteristics and pretreatment needs to prevent membranes from fouling, scaling, or other membrane degradation. Removal of suspended solids is necessary to prevent colloidal and bio-fouling, and removal of dissolved solids is necessary to prevent scaling and chemical attack. Large installation pretreatment can include media filters to remove suspended particles; ion exchange softening or antiscalant to remove hardness; temperature and pH adjustment to maintain efficiency; acid to prevent scaling and membrane damage; activated carbon or bisulfite to remove chlorine (post disinfection may be required); and cartridge (micro) filters to remove some dissolved particles and any remaining suspended particles.

Maintenance - Regular monitoring of membrane performance is necessary to determine fouling, scaling, or other membrane degradation. Use of monitoring equations to track membrane performance is recommended. Acidic or caustic solutions are regularly flushed through the system at high volume/low pressure with a cleaning agent to remove fouling and scaling. The system is flushed and returned to service. $NaHSO_3$ is a typical caustic cleaner. RO stages are cleaned sequentially. Frequency of membrane replacement depends on raw water characteristics, pretreatment, and maintenance.

Waste Disposal - Pretreatment waste streams, concentrate flows, and spent filters and membrane elements all require approved disposal.

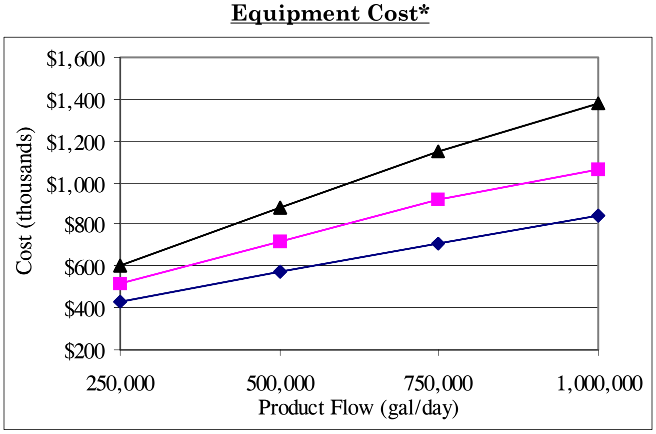
Advantages -

- Produces highest water quality.
- Can effectively treat wide range of dissolved salts and minerals, NOM, turbidity, biological, primary and secondary contaminants.
- Lower pressure, compact, self-contained, single membrane units are available for small installations.

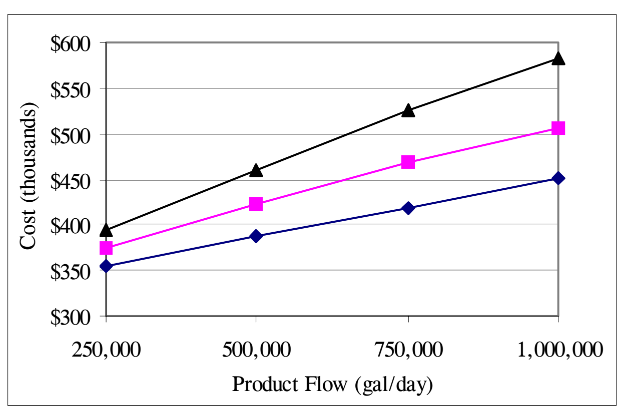
Disadvantages -

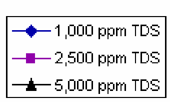
- Relatively expensive to install and operate.
- Frequent membrane monitoring and maintenance
- Pressure, temperature, and pH requirements to meet membrane tolerances. May be chemically sensitive.

Equipment Cost*



Annual O&M Cost*





*Refer to Cost Assumptions Fact Sheet. Does not include general sitework, building, external pumps/piping, pretreatment, or off-site sludge disposal.